Sept. 3, 1946. H. TUNICK 2,407,212

RADIO RELAYING

Original Filed June 16, 1942 2 Sheets-Sheet 1

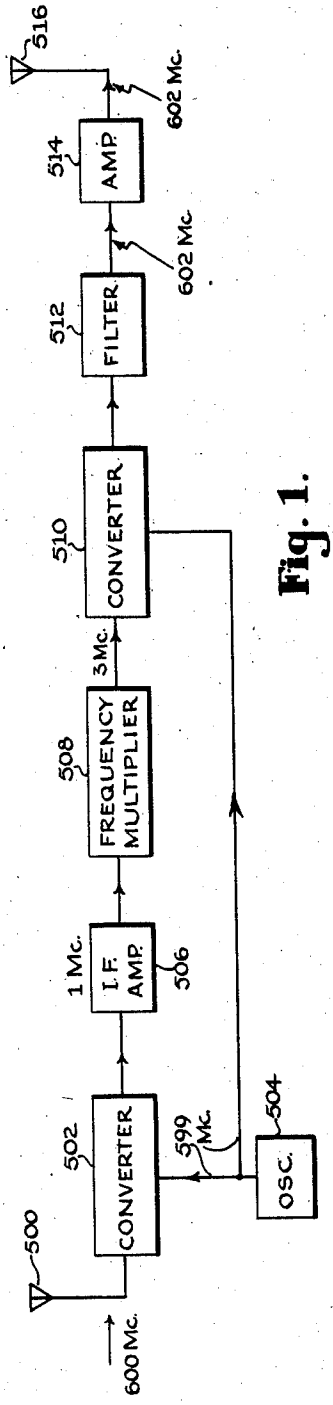


Fig. 1.

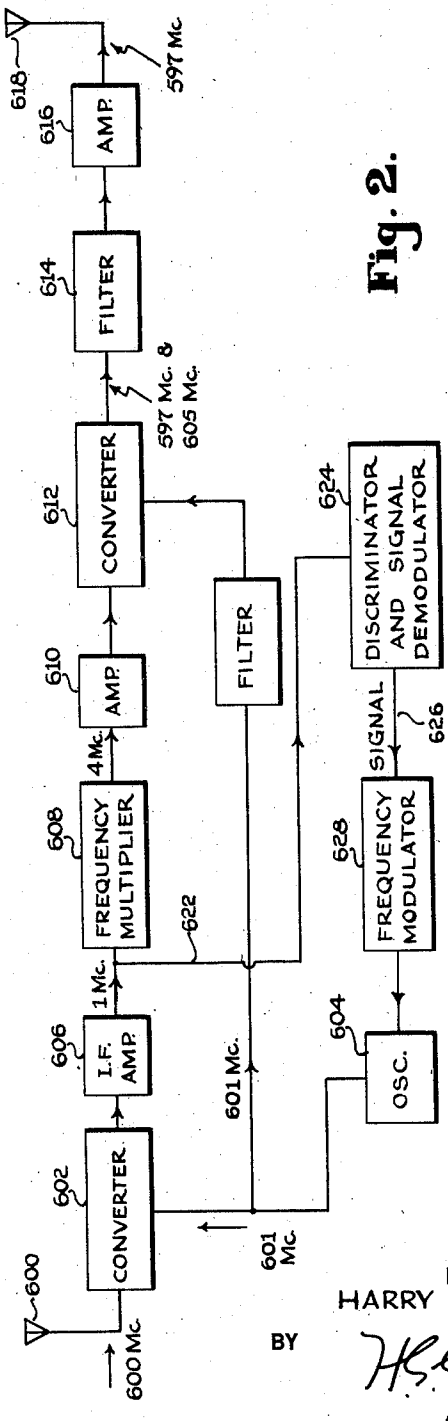


Fig. 2.

INVENTOR
HARRY TUNICK.

BY H. S. Grove

ATTORNEY

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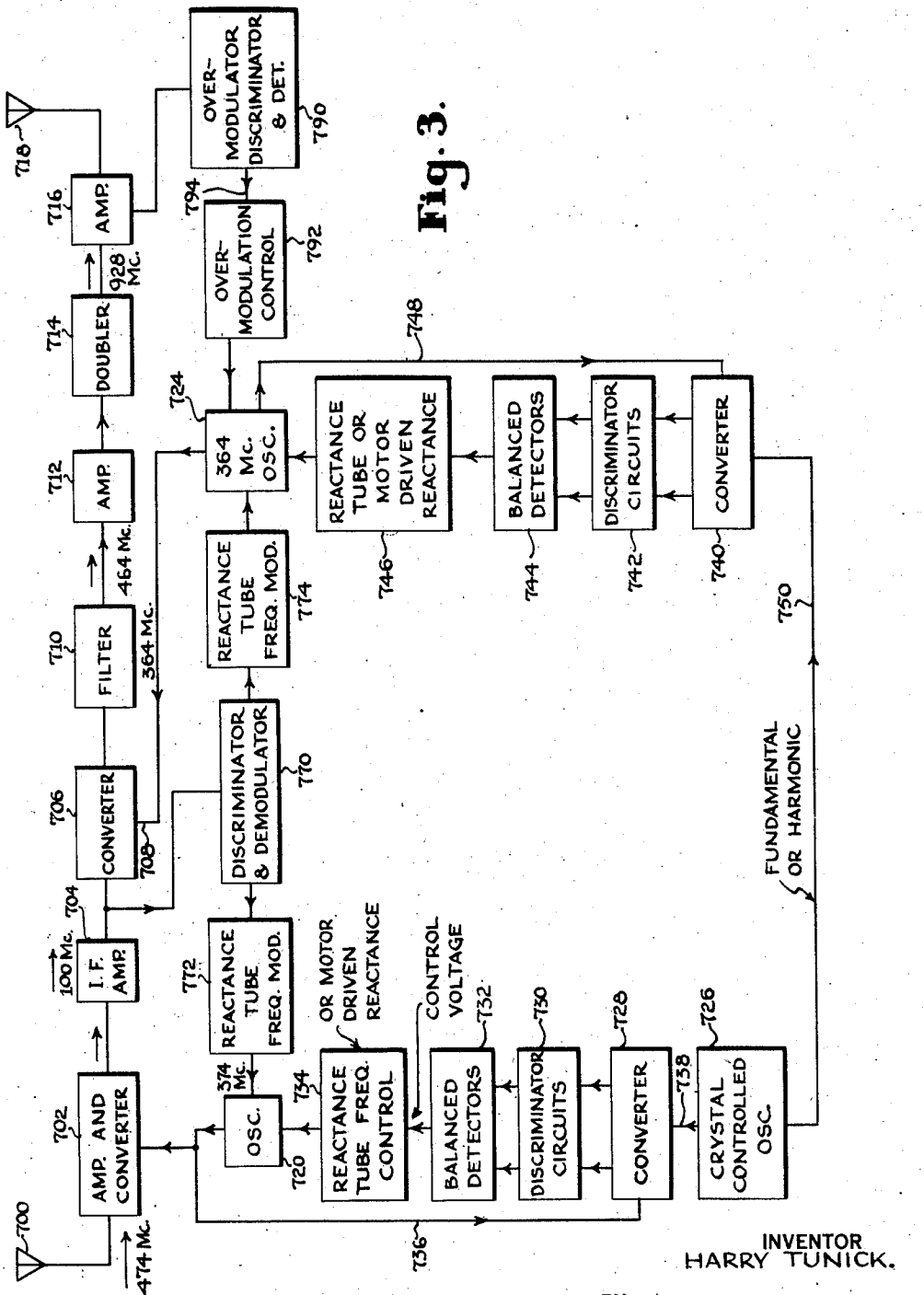


Fig. 3.

INVENTOR
HARRY TUNICK.

BY

H. S. Grove

ATTORNEY

Patented Sept. 3, 1946

2,407,212

UNITED STATES PATENT OFFICE

2,407,212

RADIO RELAYING

Harry Tunick, Rye, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Original application June 16, 1942, Serial No. 447,225. Divided and this application June 13, 1944, Serial No. 540,060

20 Claims. (Cl. 250—15)

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This invention is a division of my copending application Serial No. 447,225, filed June 16, 1942. Figures 1, 2, and 3 herein are, respectively, original Figures 5, 6, and 7 of my parent application as filed in the United States Patent Office.

Generally, my present invention relates to conversion of waves of one frequency to waves of another frequency. My invention has particular application to radio relaying systems for relaying frequency or phase modulated waves or, more generally, angle modulated waves.

One object of my present invention is to provide an improved relay for angle velocity modulated waves in which the received waves are converted to waves of different frequency and retransmitted. The conversion is accomplished with a minimum of distortion. Also, arrangements are provided whereby the retransmitted waves are maintained at a fixed frequency difference with respect to the incoming waves.

In one form of my invention received waves are heterodyned down to some intermediate frequency. The intermediate frequency is then frequency multiplied and the frequency multiplied intermediate frequency is then heterodyned back up in frequency with waves derived from the same oscillator producing the intermediate frequency. In this way drifts in frequency of the local oscillator are cancelled out and a frequency for retransmittal is obtained which does not depend upon the use of any freely oscillating oscillator at the relaying point. The frequency difference between the received and retransmitted waves, therefore, is maintained at a definite value depending upon, in the main, the frequency of the received waves.

In the event that it is desired to retransmit with the same deviation as received, I have provided instrumentalities whereby this may be accomplished without an objectionable amount of mean frequency drift and with substantial freedom from distortion.

Other modifications, features, advantages, and objects of my invention will be apparent as the more detailed description thereof proceeds.

In the accompanying drawings:

Figure 1 illustrates an arrangement wherein the difference between the retransmitted waves and the received waves is derived by frequency multiplying intermediate frequency waves;

Figure 2 illustrates an arrangement enabling the use of frequency multiplication in a relaying system without unduly expanding the frequency deviation in the retransmitted angular velocity modulated waves; and

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Figure 3 is still another form of my invention using the frequency swing reducing feature of Figure 2 together with other features, such as the automatic frequency control of a plurality of heterodyning oscillators from a single source of constant frequency oscillations and an arrangement for preventing over-modulation.

In the relaying system shown in Figure 1 a frequency modulated wave having a carrier frequency of, for example, 600 megacycles is received on a receiving antenna 500 and with or without amplification is fed to a converter 502 also supplied with waves from a local generator 504.

The difference frequency is amplified in an intermediate frequency amplifier 506 and, as indicated, the difference frequency may be made equal to one megacycle. This intermediate frequency may then be multiplied by a frequency multiplier 508 so that the mean frequency of the multiplied energy or waves is three megacycles.

The output of frequency multiplier 508, as shown, is fed to a converter 510 also supplied with waves from oscillator 504. From the output of converter 510, filter 512 selects either the upper or lower side band, here shown to be the upper side band having a mean frequency of 602 megacycles which is fed to the amplifier 514 and then radiated by radiating antenna 516.

If desired, of course, 514 may include a frequency multiplier so that the radiated frequency may be some multiple of the output of filter 512. For example, if the multiplying factor were chosen to be 3, then the mean frequency radiated by antenna 516 would be 1806 megacycles.

In the relaying system of Figure 2, assume that a frequency modulated wave or a phase modulated wave having a mean frequency of 600 mc. is received upon antenna 600. The received wave is fed with or without amplification to a converter 602 also supplied with heterodyning waves having a frequency of 601 megacycles, for example, from local oscillator and frequency multiplier, if desired, 604.

The difference frequency is separated out and amplified by the intermediate frequency amplifier 606 and this wave having a mean frequency of one megacycle for the values chosen is fed to a frequency multiplier 608. One megacycle intermediate frequency waves may be multiplied up to, for example, 4 megacycles by the action of frequency multiplier 608 and amplified in amplifier 610, heterodyned to a higher frequency in converter 612 and filtered and amplified before retransmission over antenna 618 by means of filter 614 and amplifier 616.

The waves for conversion to a higher frequency are derived from oscillator 604 and filter 620. Filter 620 may be designed so as to have a rather sharp frequency characteristic passing most freely waves having a frequency of 601 mc. for the values of frequency assumed.

Although filter 614 is illustrated to pass 597 mc., it could, of course, be designed to pass the upper side band, namely, 605 mc. which also appears in the output of converter 612.

The action of frequency multiplier 608 serves to multiply the frequency deviation in the retransmitted waves as compared to the frequency deviation representative of the signal in the received waves. If it is desired to retransmit with substantially the same deviation as that received and yet employ the frequency multiplier 608, part of the intermediate frequency output derived from intermediate frequency amplifier 606 may be fed through line 622 to a discriminator and signal demodulator 624 which may be of the type described in Patent No. 2,121,103 to S. W. Seeley.

The demodulated signal may then be fed through line 626 to a reactance tube modulator 628 for modulating the local oscillator 604 in such a way as to reduce the frequency swing in the output of intermediate frequency amplifier 606.

The reactance tube modulator circuits in the rectangle 628 for controlling or frequency modulating the oscillator 604 may use the principles of operation and the circuits shown in the patent to M. G. Crosby No. 2,279,659. The principles of reducing frequency swing by appropriately frequency modulating the heterodyning oscillator 604 are described in greater detail in my copending application Serial No. 423,763, filed December 20, 1941, now U. S. Patent No. 2,362,000.

By appropriately choosing the time constants in circuit 624, this apparatus may be used to automatically frequency control oscillator 604 without a substantial reduction in frequency swing, if desired, in order to insure that the intermediate frequency waves fall within the pass band of the intermediate frequency amplifier 606. In either event, where apparatus 624 is used for this automatic frequency controlling function or for reducing the frequency swing, connection 622 may, if desired, be coupled to the output circuit of amplifier 616.

Also, it is to be noted that with conductor 622 fed with a part of the output of amplifier 616 apparatus 624 and 628 may be designed in accordance with the principles set forth in my copending application Serial No. 310,495, filed December 22, 1939, now United States Patent 2,296,962, dated September 29, 1942, whereby the retransmitted signal is maintained substantially within an assigned channel despite any tendency towards overmodulation.

In the modification of my invention illustrated in Figure 3, let it be assumed that the incoming wave received by antenna 700 has a mean frequency of 474 megacycles and that the frequency swing produced by the strongest signal is plus and minus 6 megacycles. The received waves with or without amplification are converted in converter 702 to, for example, a lower, readily amplifiable intermediate frequency such as 100 mc. and fed to the intermediate frequency amplifier 704. The output of intermediate frequency amplifier 704 is then heterodyned up to a converter 706 with, for example, a heterodyning wave of 364 mc. received through line 708. Filter 710 may select from the output of converter 706 a

wave frequency of, for example, 464 megacycles which may be amplified in amplifier 712 and then radiated. Or, if desired, the output of amplifier 712 may be fed to a further frequency multiplier 714, for example, a doubler, further amplified by amplifier 716 and then radiated over retransmitting antenna 718.

Both of the local oscillators 720, 724 supplying heterodyning waves of 374 mc. and 364 mc., respectively, to the converters 702 and 706 are automatically frequency controlled by fundamental or harmonic frequency waves derived from a common crystal controlled oscillation generator 726.

The automatic frequency control system for oscillator 720 consists of converter 728, discriminator circuits 730, balanced detectors 732 and reactance tube frequency control circuits 734. The latter may be replaced, if desired, by a motor-driven reactance. As indicated, converter 728 is supplied with waves from oscillator 720 through line 736 and with waves of fundamental or harmonic frequency through line 738, energized by oscillator 726 or a frequency multiplier associated therewith.

The automatic frequency control system for oscillator 724 is similar and includes the converter 740, discriminator circuit 742, balanced detector 744 and reactance tube circuits or a motor-driven reactance arrangement 746. Converter 740 is fed through line 748 with waves from the oscillator 724 and through line 750 with waves of fundamental frequency or of some harmonic frequency derived from local oscillator 726.

Since both automatic frequency controlling systems are under control of a single local oscillator 726, it will be found that high frequency stability and operation within an assigned channel will be insured over long periods of time.

In the event that frequency multiplier 714 increases the deviation to an undesired amount, this effect can be reduced by feeding part of the output of the intermediate frequency amplifier 704 to a signal discriminator and demodulator 770, the output of which is used to drive either or both the reactance tube frequency modulators 772 and 774. Reactance tube frequency modulator 772 is used to frequency modulate the oscillator 720 in such a direction as to reduce the effect of frequency swing in the intermediate frequency amplifier 704. The modulator 774 is used to frequency modulate oscillator 724 in such a direction as to reduce the frequency swing in the output of filter 710. The principles of swing reduction are explained more fully in my copending application Serial No. 423,763, filed December 20, 1941, now United States Patent 2,362,000, dated Nov. 7, 1944.

If oscillators 720 and 724 are designed so as to be sufficiently stable, automatic frequency controlling apparatus 734, 736, 732, 730, 728, 738, 750, 740, 742, 744, 746, and 748 may be omitted.

To further insure that the retransmitted waves lie within an assigned channel and to prevent over-modulation apparatus 790 may be provided, the output voltage of which may be applied to the frequency modulator 774 or to an independent frequency modulator or frequency control device such as a motor-driven reactance 792. Overmodulation apparatus 790 is more fully described in my copending application Serial No. 310,495, filed December 22, 1939, now United States Patent 2,296,962, dated Sept. 29, 1942, and generally comprises two circuits tuned to or beyond the extreme frequencies of the assigned channel. The outputs of these circuits are fed to detectors

which produce rectified currents representative of over-modulation. The outputs of the detectors may then be fed through conductor 794 to, for example, a motor for changing the setting of a reactance or to a reactance tube in order thereby to change the frequency of oscillation of local oscillator 724. The frequency controlling apparatus, namely, the reactance tube or motor-driven reactance device is diagrammatically illustrated at 792. A similar device may be provided for oscillator 720 driven in parallel by the voltage appearing in conductor 794.

The frequency multipliers referred to hereinabove may be set up in accordance with the principles set forth in the patent to C. W. Hansell, No. 1,878,308. The reactance tube frequency control circuits may follow the principles set forth in the patents to M. G. Crosby, Nos. 2,227,659, 2,227,660, and 2,227,661. Amplitude limiting may not only be used in the final amplifier stages, but may also be used in the intermediate frequency amplifiers and in the initial amplifiers connected to the receiving antennas as well.

It is to be noted that the over-modulation control system of Figure 3 may, if desired, be of the type described by H. E. Goldstine in his U. S. Patent No. 2,296,919. The over-modulation control is preferably applied to oscillator 720 so that in the intermediate frequency amplifier 704 the effective swing is reduced.

I claim:

1. The method which includes heterodyning electrical waves down to an intermediate frequency, frequency multiplying the waves of intermediate frequency and heterodyning the frequency multiplied waves to a wave of higher frequency.

2. A radio relaying system comprising means for received radio waves, a source of oscillations, means for heterodyning the received waves to an intermediate frequency with waves derived from said source, a frequency multiplier for frequency multiplying the waves of intermediate frequency, and means for heterodyning the frequency multiplied waves with other waves derived from said local oscillator.

3. The method which includes heterodyning to an intermediate frequency waves of varying frequency, reducing the variations in frequency in said waves of intermediate frequency, and frequency multiplying said waves having said reduced frequency variations.

4. The method which includes heterodyning frequency modulated waves to a convenient intermediate frequency, reducing the frequency swing of the waves of intermediate frequency, frequency multiplying the waves of intermediate frequency having the reduced swing, and heterodyning the frequency multiplied waves to a higher frequency.

5. In combination, a source of waves, means for heterodyning said waves to an intermediate frequency, said heterodyning means comprising an oscillation generator, means for heterodyning said intermediate frequency waves to still another frequency, said last-mentioned means comprising another oscillation generator, and means for automatically frequency controlling said oscillation generators, said automatic frequency controlling means comprising a common source of oscillations of substantially constant frequency.

6. The method of relaying frequency modulated waves which includes heterodyning the waves to an intermediate frequency, reducing the frequency swing in the waves of intermediate frequency, and frequency multiplying the waves of reduced swing.

7. The method of relaying frequency modulated waves which includes heterodyning the waves to an intermediate frequency, reducing the swing of the waves of intermediate frequency, heterodyning the waves of reduced swing to a higher frequency, reducing the frequency swing of the waves of said higher frequency, and frequency multiplying said last-mentioned waves.

8. A radio relay system comprising an antenna for receiving a radio signal to be relayed, a local generator, a converter in which said received waves and waves from said generator are combined to produce waves of a relatively low intermediate frequency, a frequency multiplier for frequency multiplying said waves of intermediate frequency, a second converter for combining the frequency multiplied waves and waves from said generator, and a second antenna for transmitting waves under control of the output of said second converter.

9. The method of relaying phase or frequency modulated waves which includes receiving such modulated waves, generating local oscillations, heterodyning the received waves with a portion of said locally generated waves so as to produce intermediate frequency waves of relatively low frequency, frequency multiplying said intermediate frequency waves, heterodyning said frequency multiplied waves with another portion of said locally generated waves to a relatively high frequency, filtering and amplifying said relatively high intermediate frequency waves, and reradiating said filtered and amplified waves.

10. The method of relaying received phase or frequency modulated high frequency waves which includes receiving said waves, heterodyning the waves down to a relatively low intermediate frequency, discriminating and detecting a portion of said intermediate frequency waves, utilizing said detected waves to reduce the frequency or phase deviation of said relatively low intermediate frequency waves, frequency multiplying the waves of reduced frequency or phase deviation, heterodyning the waves of reduced deviation to a higher frequency, filtering the heterodyned waves, and utilizing the filtered waves.

11. Apparatus for relaying phase or frequency modulated waves, comprising a local generator of oscillations, a converter to which waves from said generator and received waves are fed and heterodyned together to produce an intermediate frequency wave, an intermediate frequency amplifier for amplifying said intermediate frequency wave, discriminator-detector apparatus coupled to the output of said intermediate frequency amplifier for discriminating and detecting a portion thereof, a frequency modulator for utilizing the output of said discriminator-detector apparatus to frequency modulate wave energy derived from said local generator which is fed to said converter, a frequency changer coupled to said intermediate frequency amplifier for changing the mean frequency of another portion of the wave output of said intermediate frequency amplifier, heterodyning apparatus for heterodyning the output of said frequency changer to a higher frequency, and circuits for utilizing the energy of higher frequency.

12. A relaying system for phase or frequency modulated waves comprising a receiving antenna, a converter to which waves received by said antenna are fed, a source of local oscillations, circuits for feeding waves from said local source

to said converter whereby waves of intermediate frequency are produced by said converter, an intermediate frequency amplifier for amplifying waves of intermediate frequency produced by said converter, discriminator-detector apparatus for discriminating and detecting a portion of the output of said intermediate frequency amplifier, a frequency modulator responsive to the output of said discriminator-detector apparatus for frequency modulating said locally generated waves in such a direction as to reduce the effective deviation of waves appearing in the output of said intermediate frequency amplifier, a frequency multiplier for frequency multiplying the waves of reduced deviation, apparatus for heterodyning the output of said frequency multiplier with wave energy derived from said local generator to a relatively high frequency, apparatus for filtering said relatively high frequency wave energy, and a radiating antenna for radiating waves derived from said filtered relatively high frequency waves.

13. Apparatus for relaying phase or frequency modulated waves comprising means for receiving waves, a local generator of oscillations, a converter to which waves from said generator and waves derived from said receiving means are fed and heterodyned together to produce an intermediate frequency wave, a reactance tube modulating circuit connected to said generator, an intermediate frequency amplifier for amplifying said intermediate frequency wave produced by said converter, a second local generator of oscillations, a mixer in which waves from said intermediate frequency amplifier and from said second local oscillation generator are mixed to produce waves of relatively high frequency, a second reactance tube frequency modulator connected to said second local generator of oscillations, means for operating said reactance tube frequency modulators whereby oscillations generated by said local generators are frequency modulated, filtering apparatus coupled to the output of said mixer, and transmitting apparatus for transmitting the output of said filter.

14. Apparaus as claimed in the preceding claim, characterized by the provision of a frequency multiplier connected intermediate said mixer and transmitting apparatus.

15. Radio relaying apparatus for phase or frequency modulated waves comprising means for receiving waves to be relayed, a source of heterodyning oscillations, a first mixer in which waves derived from the received waves and waves derived from said source are combined to produce a wave of intermediate frequency, a frequency multiplier for frequency multiplying the waves of intermediate frequency, a converter coupled to said frequency multiplier, a second source of local oscillations, means for connecting said second source to said converter, transmitting apparatus for transmitting waves derived from the output circuit of said converter, a discriminator-demodulator system connected to said transmitting apparatus, and means for connecting the output of said discrminator-demodulator system to one of said local oscillation generators in such a way as to control and vary the frequency thereof.

16. Apparatus for relaying phase or frequency modulated waves comprising means for receiving waves, a local generator of oscillations, a converter to which waves from said generator and waves derived from said receiving means are fed and heterodyned together to produce an intermediate frequency wave, a reactance tube modulating circuit connected to said generator, an intermediate frequency amplifier for amplifying said intermediate frequency wave produced by said converter, a second local generator of oscillations, a mixer in which waves from said intermediate frequency amplifier and from said second local oscillation generator are mixed to produce waves of relatively high frequency, a second reactance tube frequency modulator connected to said second local generator of oscillations, a source of control potentials, means for connecting said reactance tube frequency modulators to said source of control potentials whereby oscillations generated by said local generators are varied in frequency in accordance with said control potentials, filtering apparatus coupled to the output of said mixer, and transmitting apparatus for transmitting the output of said filter.

17. Radio relaying apparatus for phase or frequency modulated waves comprising means for receiving waves to be relayed, a source of heterodyning oscillations, a first mixer in which waves derived from the received waves and waves derived from said source are combined to produce a wave of intermediate frequency, an amplifier for amplifying said wave of intermediate frequency, a converter coupled to said amplifier, a second source of local oscillations, means for connecting said second source to said converter, transmitting apparatus for transmitting waves derived from the output circuit of said converter, a discriminator-demodulator system connected to said transmitting apparatus, and means for connecting the output of said discriminator-demodulator system to one of said local oscillation generators in such a way as to control and vary the frequency thereof.

18. Apparatus for relaying phase or frequency modulated waves comprising means for receiving waves, a local generator of oscillations, a converter to which waves from said generator and waves derived from said receiving means are fed and heterodyned together to produce an intermediate frequency wave, a reactance tube modulating circuit connected to said generator, an intermediate frequency amplifier for amplifying said intermediate frequency wave produced by said converter, a second local generator of oscillations, a mixer in which waves from said intermediate frequency amplifier and from said second local oscillation generator are mixed to produce waves of relatively high frequency, a second reactance tube frequency modulator connected to said second local generator of oscillations, means for producing modulating waves, means for connecting said last-mentioned means for producing modulating waves to said frequency modulators whereby oscillations generated by said local generators are frequency modulated, means for filtering the output of said mixer, and transmitting apparatus for transmitting the output of said filtering means.

19. Apparatus for relaying phase or frequency modulated waves comprising means for receiving waves, a local generator of oscillations, a converter to which waves from said generator and waves derived from said receiving means are fed and heterodyned together to produce an intermediate frequency wave, an intermediate frequency amplifier for amplifying said intermediate frequency wave produced by said converter, a second local generator of oscillations, a mixer in which waves from said intermediate frequency amplifier and from said second local oscillation generator are mixed to produce waves of rela-

tively high frequency, a reactance tube frequency modulator connected to one of said local generators of oscillations, means responsive to modulating waves for operating said reactance tube frequency modulator whereby oscillations generated by said local generator to which said modulator is connected are frequency modulated, filtering apparatus coupled to the output of said mixer, and transmitting apparatus for transmitting the output of said filtering apparatus.

20. Apparatus for relaying phase or frequency modulated waves comprising means for receiving waves, a local generator of oscillations, a converter to which waves from said generator and waves derived from said receiving means are fed and heterodyned together to produce an intermediate frequency wave, an intermediate frequency amplifier for amplifying said intermediate frequency wave produced by said converter, a second local generator of oscillations, a mixer in which waves from said intermediate frequency amplifier and from said second local oscillation generator are mixed to produce waves of relatively high frequency, a frequency modulator circuit connected to one of said generators of oscillations, means responsive to modulating potentials for operating said frequency modulator circuit whereby oscillations generated by said local generator to which said modulator circuit is connected are frequency modulated, and transmitting apparatus connected to the output circuit of said mixer.

HARRY TUNICK.